2002-06

Optimal selection of Army military construction projects

Dzwonchyk, James D.

Monterey, California. Naval Postgraduate School

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

OPTIMAL SELECTION OF ARMY MILITARY CONSTRUCTION PROJECTS

by

James D. Dzwonchyk

June 2002

Thesis Advisor:	Robert F. Dell
Co-Advisor:	William J. Tarantino
Second Reader:	Eva D. Regnier

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** June 2002	**3. REPORT TYPE AND DATES COVERED** Master's Thesis	
4. TITLE AND SUBTITLE: Optimal Selection of Army Military Construction Projects			**5. FUNDING NUMBERS**
6. AUTHOR(S) James D. Dzwonchyk			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of the Assistant Chief of Staff for Installation Management Construction Division, ATTN: Pete Tamilin Washington, DC 20310 Center for Army Analysis 6001 Goethals Road, ATTN: LTC William J. Tarantino Fort Belvoir, VA 22060			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release, distribution is unlimited.			**12b. DISTRIBUTION CODE**

13. ABSTRACT

The Assistant Chief of Staff for Installation Management (ACSIM) manages all Army military construction (MILCON) implementation and requests. Annually, the ACSIM submits a prioritized list of MILCON projects requiring Congressional approval. Typically, Congress does not approve all Army requests. This thesis develops an integer linear program, PESA (Project Evaluation and Selection Assistant), to assist the ACSIM evaluate and select the best set of MILCON projects under various policies and budgets; thus assisting ACSIM develop a defendable set of MILCON projects to submit to Congress. Using a budget of $600 million (funds allocated in fiscal year 2001) and data for 62 projects for fiscal year 2001, we recommend funding a set of 50 projects that adhere to the following: fund each Major Army Command's projects in priority; limit each Major Army Command to less than 25% of the total budget; and use at least 80% of the total budget on the worst condition facilities. We demonstrate how this set of 50 projects better adheres to Army policies than those that would be recommended by the current Army technique.

14. SUBJECT TERMS Military Construction, Project Selection, Integer Linear Programming, Optimization, Facilities, Optimal Funding			**15. NUMBER OF PAGES** 69
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UL

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release, distribution is unlimited.

OPTIMAL SELECTION OF ARMY MILITARY CONSTRUCTION PROJECTS

James D. Dzwonchyk
Captain, United States Army
B.S., United States Military Academy, 1993

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
June 2002

Author: James D. Dzwonchyk

Approved by: Robert F. Dell, Thesis Advisor

William J. Tarantino, Co-Advisor

Eva D. Regnier, Second Reader

James N. Eagle, Chairman
Department of Operations Research

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

The Assistant Chief of Staff for Installation Management (ACSIM) manages all Army military construction (MILCON) implementation and requests. Annually, the ACSIM submits a prioritized list of MILCON projects requiring Congressional approval. Typically, Congress does not approve all Army requests. This thesis develops an integer linear program, PESA (Project Evaluation and Selection Assistant), to assist the ACSIM evaluate and select the best set of MILCON projects under various policies and budgets; thus assisting ACSIM develop a defendable set of MILCON projects to submit to Congress. Using a budget of $600 million (funds allocated in fiscal year 2001) and data for 62 projects for fiscal year 2001, we recommend funding a set of 50 projects that adhere to the following: fund each Major Army Command's projects in priority; limit each Major Army Command to less than 25% of the total budget; and use at least 80% of the total budget on the worst condition facilities. We demonstrate how this set of 50 projects better adheres to Army policies than those that would be recommended by the current Army technique.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS

ACSIM	Assistant Chief of Staff for Installation Management
AFS	Army Facilities Strategy
AMC	United States Army Materiel Command
ANP	Analytic Network Process
ATEC	Army Test and Evaluation Command
BEQ	Bachelor Enlisted Quarters
BOQ	Bachelor Officer Quarters
CID	United States Army Criminal Investigation Command
CRRC	Construction Requirements Review Committee
DAIM-FD	Department of the Army for Installation Management, Facilities Division
DAR	Defense Access Roads
DD	Department of Defense
EUSA	Eighth United States Army Korea
FORSCOM	United States Army Forces Command
G3	Deputy Chief of Staff for Operations
HQUSACE	Headquarters United States Army Corps of Engineers
INSCOM	United States Army Intelligence and Security Command
ISR	Installation Status Report
MACOM	Major Army Command
MDW	United States Army Military District of Washington
MEDCOM	United States Army Medical Command
MEPCOM	Military Entrance Processing Command
MILCON	Military Construction
MTMC	Military Traffic Management Command
NSE	Navy Scoring Equation
PESA	Project Evaluation and Selection Assistant
PRB	Project Review Board
PRV	Plant Replacement Value
SE	Scoring Equation
TRADOC	United States Army Training and Doctrine Command
USAREC	United States Army Recruiting Command
USAREUR	United States Army Europe
USARPAC	United States Army Pacific Command
USMA	United States Military Academy

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

I wish to express my appreciation to Professor Robert Dell for his guidance and instruction. His caring attitude and untiring support has made this thesis a rewarding educational experience. I would also like to thank LTC William Tarantino for his assistance and mentorship throughout the research process. I would also like to thank Professor Eva Regnier for providing insights and advice on my thesis. I would also like to thank Pete Tamilin, Construction Division in the Office of the Assistant Chief of Staff for Installation Management, and others in the Office of the Assistant Chief of Staff for Installation Management, for taking the time away from their busy schedules to assist me in understanding this problem and in explaining the MILCON process in a clear and concise manner.

Finally, I thank my wife, Helen, and daughter, Casey, for their continued support and patience not only during this thesis, but as always throughout all my endeavors.

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

The Assistant Chief of Staff for Installation Management (ACSIM) manages all Army military construction (MILCON) implementation and requests. Annually, the ACSIM submits a prioritized list of MILCON projects that require Congressional approval. Typically, Congress does not approve all Army requests. This thesis develops an integer linear program, PESA (Project Evaluation and Selection Assistant), to assist the ACSIM evaluate and select the best set of MILCON projects under various policies and budgets; thus assisting the ACSIM develop a defendable set of MILCON projects to submit to Congress.

As of 2002, the Army uses a scoring equation for project selection which awards points in four areas: Major Army Command (MACOM) priority score (maximum points allowable is 60), Installation Status Report (ISR) score (maximum points allowable is 20), Project Review Board (PRB) scoring (maximum points allowable is 15), and MILCON Team Assessment (maximum points allowable is 5). Based on the total score, n projects are ranked from 1 to n. Although this scoring equation is an improvement compared to past practices of ranking projects, the Army desires a better way to select projects and requested this thesis.

We demonstrate PESA using fiscal year 2001 project data provided by the ACSIM and various budget amounts to develop several excursions. Each excursion varies the number of constraints enforced (representing different levels of adherence to Army policies) and budget. PESA's results enable ACSIM to justify projects they are funding and/or to request additional dollars to fund certain sets of projects that adhere to stated policies.

Eleven recommended options representing various policies and budget present the ACSIM different funding options and project selection packages. Using a budget of $600 million (funds allocated in fiscal year 2001) and data for 62 projects for fiscal year 2001, we recommend funding a set of 50 projects that adhere to the following: fund each Major Army Command's projects in priority; limit each Major Army Command to less than 25% of the total budget; and use at least 80% of the total budget on the worst condition

facilities. We demonstrate how this set of 50 projects better adheres to Army policies than those that would be recommended by the current Army technique.

I. ARMY MILITARY CONSTRUCTION PROJECTS

The Army's military construction (MILCON) requests compete annually for funding. For fiscal year 2002, the Army received over $1.76 billion for MILCON [Tamilin 2001a]. The Assistant Chief of Staff for Installation Management (ACSIM) manages the Army MILCON requests and implementation. Once a year, the ACSIM submits a prioritized list of MILCON projects that require Congressional approval. Typically, Congress does not approve all Army requests. This thesis develops an integer linear program, PESA (Project Evaluation and Selection Assistant), to assist the ACSIM evaluate and select the best set of MILCON projects under various policies and budgets; thus assisting the ACSIM develop a defendable set of MILCON projects to submit to Congress.

A. BACKGROUND

There are two Army MILCON project categories: centralized and revitalization. Centralized projects include any related to strategic mobility, barracks, and projects covered under the Army Facility Strategy [Klug and Lynah 2001] such as: chapels, fitness facilities, general instruction buildings, and initial entry training complexes. The Army plans, programs, and budgets these projects in coordination with the Major Army Commands (MACOMs) [Tamilin 2001b]. For the purpose of this thesis, MACOM refers to the Major Army Commands and other Higher Headquarters, for example, ATEC (Army Test and Evaluation Command) and USAREC (United States Army Recruiting Command). All other projects are revitalization projects and are the focus of this thesis. These projects replace existing inventory and require Congressional review and approval. In fiscal year 2002, these projects accounted for approximately 40% of the Army MILCON budget. Examples of revitalization projects are: M16 firing ranges, military entrance processing stations, and child development centers.

1. Army MILCON Project Review

Before the ACSIM sees a project, it is subject to numerous reviews. A project's MILCON request begins at its installation, where each installation Commander identifies his requirements and submits a prioritized list to his respective MACOM. The MACOMs produce a prioritized list of all projects from the lists submitted by their respective installation Commanders.

a. Army Project Review Board

The Army Project Review Board (PRB) meets annually (typically March or April) to review MILCON requests for projects that are proposed to begin construction in three fiscal years. For example, the PRB meeting in April 2002 reviews projects that would begin construction in fiscal year 2005.

Approximately three months prior to the PRB, the MACOMs submit a DD Form 1391 [United States Publishing Agency 1999] for each project to the ACSIM and Headquarters United States Army Corps of Engineers (HQUSACE). HQUSACE reviews the documents for correctness (e.g., cost estimation and requirements). The MACOMs brief their projects using their DD Form 1391s to the Army Construction Requirements Review Committee (CRRC) at the PRB. The CRRC members, chosen from the Department of the Army Staff, review each project with each member scoring each project on a scale from one (lowest) to five (highest).

The PRB computes an average score (called the PRB score, calculated by summing each CRRC member's score divided by the number of CRRC members) for each project and then, ranks the projects based on their respective PRB scores. At the ACSIM's discretion, he may adjust the ranking before submitting the list to the Deputy Chief of Staff for Operations (G3) for final approval. But any ACSIM adjustment traditionally attempts to maintain MACOM priority. For example, a MACOM project priority three would not be place ahead of its priority one on the list submitted to G3. After obtaining the G3 approval, ACSIM submits the list to Congress.

B. SCORING ARMY MILCON PROJECTS

Starting in April 2002, the ACSIM prioritized MILCON revitalization projects using the following project scoring equation (SE) [Sugiyama 2001]:

PROJECT SCORE = MACOM PRIORITY SCORE + ISR CONDITION ASSESSMENT SCORE + PRB SCORING + MILCON TEAM ASSESSMENT.

The maximum PROJECT SCORE is 100. For the fiscal year 2001 PRB project data, the minimum PROJECT SCORE is 29.31. Similar to the technique described above, the ACSIM ranks the projects from highest project score to lowest project score and submits this list to Congress for approval. Below we repeat the PROJECT SCORE equation and review the four areas comprising it.

1. MACOM PRIORITY SCORE

(PROJECT SCORE = **MACOM PRIORITY SCORE** + ISR CONDITION ASSESSMENT SCORE + PRB SCORING + MILCON TEAM ASSESSMENT.)

The Center for Army Analysis [Tarantino 2001] develops the **MACOM PRIORITY SCORE**:

$$60 + ((1+P) * 7 * (1 - MACOM\ rank)).$$

The *MACOM rank* is an integer between one and the number of projects submitted by a MACOM. Thus, each MACOM's first priority project (*MACOM rank* 1) receives a **MACOM PRIORITY SCORE** of 60. The "(1+*P*)*7" factor, where *P* is a decimal value between zero and one (based on the Plant Replacement Value (PRV) and population for each MACOM), distinguishes between MACOM projects with a similar priority [Tarantino 2001]. Generally, *P* is smaller for larger MACOMs.

2. ISR CONDITION ASSESSMENT SCORE

(PROJECT SCORE = MACOM PRIORITY SCORE + **ISR CONDITION ASSESSMENT SCORE** + PRB SCORING + MILCON TEAM ASSESSMENT.)

The Installation Status Report (ISR) is a Department of the Army report providing an evaluation of the status of installations by measuring their performance against a set of

Army-wide standards [Fasolo 2001]. The ISR covers infrastructure, environment, and services categories, but only the infrastructure ISR rating is used to compute the **ISR CONDITION ASSESSMENT SCORE**. The infrastructure ISR rating, called a C-Rating, provides both quality and quantity assessments (discussed below) for each facility that falls into one of five facility types (from most important to least important): mission support, mobility, housing, community, and installation support [Tamilin 2001b]. Each facility type receives a condition rating from C1 being the best to C4 being the worst (Table 1). The lower rating of quantity and quality becomes the ISR rating used to determine the **ISR CONDITION ASSESSMENT SCORE**.

C-rating	Quantity	Quality
C1	Installation has greater than 95% of the required facilities	Installation's facilities meet both Army standards and unit needs
C2	Installation has greater than 80% percent of what it requires	Meets unit needs and partly meets Army standards
C3	Installation has greater than 60% of what it requires	Meets majority of unit needs, but does not meet Army standards
C4	Installation has less than 60% of what it requires	Facilities are in poor condition and do not meet Army standards

Table 1. Description of ISR C-Ratings

The infrastructure ISR rating, called a C-Rating, provides both quality and quantity assessments. The rating of C1 is the highest and C4 is the lowest. The lower rating of quantity and quality becomes the ISR condition rating used to compute the **ISR CONDITION ASSESSMENT SCORE**.

Table 2 is the assigned **ISR CONDITION ASSESSMENT SCORE** for a project [Sugiyama 2001].

	Mission Support	Mobility	Housing	Community	Installation Support
C4	20	19.5	19	18.5	18
C3	17.5	17	16.5	16	15.5
C2	15	14.5	14	13.5	13
C1	12.5	12	11.5	11	10.5

Table 2. **ISR CONDITION ASSESSMENT SCORE** Matrix

The **ISR CONDITION ASSESSMENT SCORE** gives points based on the ISR facility category type and condition rating. For a mission support facility type and the worst ISR condition rating (C4), a project earns an **ISR CONDITION ASSESSMENT SCORE** of 20. For an installation support facility type and the best ISR condition rating (C1), a project earns an **ISR CONDITION ASSESSMENT SCORE** of 10.5.

3. PRB SCORING

(PROJECT SCORE = MACOM PRIORITY SCORE + ISR CONDITION ASSESSMENT SCORE + **PRB SCORING** + MILCON TEAM ASSESSMENT.)

As previously mentioned, MACOMs brief their projects to the PRB. After computing the average score (PRB score) for the project, it gets multiplied by three to provide the **PRB SCORING** (with a maximum value of 15).

4. MILCON TEAM ASSESSMENT

(PROJECT SCORE = MACOM PRIORITY SCORE + ISR CONDITION ASSESSMENT SCORE + PRB SCORING + **MILCON TEAM ASSESSMENT**.)

Members in the Construction Division branch of the ACSIM form the MILCON Assessment Team. They award points to a project for meeting certain criteria in six different areas found on the DD Form 1391 [United States Publishing Agency 1999]. Summing the points for each area (Table 3) yields the **MILCON TEAM ASSESSMENT** with a maximum value of five [Sugiyama 2001].

Area	Criteria	Points awarded
Efficiencies	Does the project offer a return on investment? Does the project consolidate or collocate functions? Does the project demonstrate joint use potential? Does the project positively affect on-post and off-post operations?	1.00
Mission timing	Does the project preclude leasing or using temporary facilities? Does the project support synchronized arrival of new mission? Does the project use sound phasing plans?	1.00
Design build	Does the project use design build procurement [DAIM-FD 2000]?	1.00
Demolition or Facilities Reduction	Does the project replace a like existing structure allowing for 100% demolition of the existing structure? Does the project eliminate relocatables, leases, or temporary facilities?	0.75
Demolition or Limited Growth	Does the project replace a like existing structure allowing for 50% demolition of the existing? Does the project eliminate relocatables, leases, or temporary facilities by 50%?	0.25
Sustainable Design	Does the project use sustainable design components [Federal Facilities Council Technical Report No. 142 2001]?	1.00

Table 3. **MILCON TEAM ASSESSMENT** Scoring Matrix

The first column comprises the six different areas the MILCON Assessment Team awards points. The second column defines the criteria for each area. The third column defines the points awarded for meeting the criteria. A project receives points only once in each area. For example, if a project demonstrates joint use potential in the efficiencies area and doesn't meet any other criteria, the **MILCON TEAM ASSESSMENT** for this project is 1.00.

C. THESIS CONTRIBUTION AND ORGANIZATION

Although the new SE directly addresses most elements considered important for selection of Army MILCON projects and is an improvement over their past methods of ranking projects, the Army desires a better way to evaluate and select projects to recommend for funding. The SE does not capture all elements that influence MILCON. Foremost, project cost is not directly considered and project cost can vary substantially. For the projects considered by the 2001 PRB, project cost varies between $1.6M and $134.0M.

In addition to ignoring project cost, the current SE has an arbitrary way of combining important factors. The SE scores and ranks *n* projects from 1 to *n*. This ranking can result in MACOMs with few projects requested (typically smaller MACOMs

by number of installations), receiving all projects and MACOMs with more project requests (generally larger MACOMs by number of installation) not allowing lower priority projects much consideration.

This thesis develops an integer linear program, PESA, to assist the ACSIM evaluate and select the best set of MILCON projects under various policies and budgets. PESA directly accounts for project cost and makes the tradeoffs between project cost and other factors explicit. With PESA, the ACSIM can investigate varying levels of adherence to Army MILCON policies and better support its funding request to Congress.

Chapter II reviews Navy and Air Force MILCON prioritization equations and other models in the operations literature for project selection. Chapter III provides the model formulation. Chapter IV reports the execution of the model using the Fiscal year 2001 PRB project data. Chapter IV also analyzes the output of PESA's runs by altering enforcement of certain constraints and budgets, policy excursions focusing on requesting budget, and a comparison to the Army SE. Chapter V provides conclusions and recommendations for future work.

THIS PAGE INTENTIONALLY LEFT BLANK

II. LITERATURE REVIEW

The Army technique to rank MILCON projects is similar to the other US services. We review how the Navy and Air Force rank projects and compare PESA to some similar industry project selection approaches reported in the operations research literature.

A. OTHER DOD MILCON PROJECT SCORING EQUATIONS

1. Navy Project Score

The Navy uses the following equation (NSE) to score its projects [Turner 2001]:

PROJECT SCORE = PROGRAMMATIC CATEGORY + INSTALLATION MANAGEMENT
CLAIMANT PRIORITY+ N44 ASSESSMENT + PERCENT OF REQUIREMENT
CURRENTLY ADEQUATE (BACHELOR HOUSING ONLY)
+ OTHER CONSIDERATIONS.

Using Turner [2001], we determined the maximum possible score is 2,280. We explain each part of NSE in the following sections.

a. PROGRAMMATIC CATEGORY

Each project is placed in an appropriate programmatic category that gives it the maximum points (Table 4). Multiplying the category points by 50 yields the value for PROGRAMMATIC CATEGORY. For example, an airfield receives 10 points multiplied by 50 yielding a value for PROGRAMMATIC CATEGORY of 500.

Points	Category
10	Airfield or waterfront restoration or modernization New mission Special restoration or modernization initiatives Higher authority priority Bachelor enlisted quarters (BEQ) deficit reduction BEQ restoration
9	Overseas community support Major equipment delivery

Points	Category
	Initial operating capability
8	Restoration and modernization Training range support Single sailor and community support Class I environmental (corrects a violation of an environmental law or regulation) BEQ modernization Explosive safety Facility consolidation
7	In-service engineering Training
6	Class II environmental (if corrective actions are not taken, develops into a Class I) Safety and health Utility systems upgrades Research, development, test, and evaluation
4	Operations and readiness
2	Administration or base support Bachelor officer quarters (BOQ)

Table 4. Programmatic Category Points Matrix

The first column is the points awarded. The second column defines the categories for each project. For example, a pier (category: waterfront restoration) receives ten points even though it can be defined in other categories [Turner 2001].

b. INSTALLATION MANAGEMENT CLAIMANT PRIORITY

A Navy claimant is similar to an Army MACOM. Turner [2001] determines the INSTALLATION MANAGEMENT CLAIMANT PRIORITY from the claimant's target total and costs of the individual projects, where the target total is based on: backlog of projects, historic funding levels, and PRV of Navy MILCON funded facilities [Turner 2001]. The INSTALLATION MANAGEMENT CLAIMANT PRIORITY attempts to maintain fairness in the amount of dollars each claimant receives by lowering the score for too many high cost projects for a given claimant [Turner 2001]. The INSTALLATION MANAGEMENT CLAIMANT PRIORITY value ranges between 7 and 700.

c. N44 ASSESSMENT

N44 is the facilities and engineering division for the Navy [Navy Facilities Engineering Command 1999]. N44 ASSESSMENT typically parallels the CLAIMANT PRIORITY and has a maximum score of 20, unless there is something wrong (e.g., viable

economic alternatives not explored) that needs to be reflected in the final score. N44 assessment seems similar to the oversight provided by the PRB for the Army SE.

d. PERCENT OF REQUIREMENT CURRENTLY ADEQUATE (BACHELOR HOUSING ONLY)

PERCENT OF REQUIREMENT CURRENTLY ADEQUATE (BACHELOR HOUSING ONLY) scores projects at activities with a low percentage of adequate housing. Turner [2001] calculates the percentage from the Bachelor Housing Facilities Current Assets Summary Report [Navy Facilities Engineering Command 1999]. This percentage (Table 5) is similar to Army's ISR rating for quantity.

After determining the percent adequate bachelor housing, multiply the points awarded by a weight of 20. The result is the PERCENT OF REQUIREMENT CURRENTLY ADEQUATE (BACHELOR HOUSING ONLY). For example, an activities' bachelor housing percent adequate of 25% receives a score of 120 (6 points*20).

Percent Adequate	Points awarded
0-10	10
11-20	8
21-30	6
31-40	4
41-50	2

Table 5. Percent Adequate Bachelor Housing

The first column is the percent of requirements adequate. The second column is the points awarded for the percent adequate. For example, 8 points are awarded if 11-20 percent of bachelor housing is considered adequate.

e. OTHER CONSIDERATIONS

OTHER CONSIDERATIONS are points for meeting certain criteria. The Army's MILCON team assessment is similar in approach, although the number of points awarded differs. The value for OTHER CONSIDERATIONS ranges from -200 up to 860. The following is a list of project criteria:

1. Economic payback
2. Previously approved (projects approved for the budget year, but deferred during budget reductions)
3. Demolition
4. Anti-terrorism or force protection
5. Quality of life in the workplace
6. Higher authority interest
7. Environmentally friendly or sustainable design
8. No off-base options
9. Supports joint use
10. Economic advantages
11. Bachelor Quarters eliminates gang heads, life, safety, or health, or supports new mission (points in each area)
12. Tough sell (e.g., projects that encounter difficulty getting through the budget process can receive negative points)

2. Air Force MILCON Project Scoring

The Air Force SE influenced the development of the Army SE. Therefore, their project scoring is very similar to the Army. The Air Force SE comprises four weighted areas based on a 100 point scoring system:

PROJECT SCORE = MAJOR COMMAND'S PRIORITY + INVESTMENT STRATEGY SCORING + CORPORATE PANEL POINTS + MILCON TEAM FACTORS.

Table 6 illustrates the similarities of the equation components between the Army and Air Force equation:

Army	**Air Force**
MACOM priority score	MAJCOM priority score
ISR condition assessment score	Investment strategy scoring
PRB scoring	Corporate panel points
MILCON team assessment	MILCON team factors

Table 6. Comparison of Army and Air Force equation components

Similar to the Army, the most important factor in the Air Force SE is the Major Commands priority. The highest value is 60 and decreases by a factor based on the size of the command's PRV yielding a MAJOR COMMAND'S PRIORITY [Smith 1999].

The INVESTMENT STRATEGY SCORING relates the project mission category and mission impact. The four mission categories are: modernization and force structure (A), readiness and sustainability (B), community support (C), and other (D). The three mission impact areas are: critical (1), degraded (2), and enhancement (3).

	A	**B**	**C**	**D**
1	35	34.5	34	33.5
2	33	32.5	32	31.5
3	31	30.5	30	29.5

Table 7. Investment Strategy Scoring Matrix [Smith 1999]

The first column is the mission impact area (from most important to least important). The first row is the mission categories (from most important to least important). For example, a project in community support (C) in a degraded mode (2) receives 32 points as the INVESTMENT STRATEGY SCORING.

The third component of the equation is the CORPORATE PANEL POINTS. The maximum points allowable are two. Their duties and responsibilities are similar to the Army's PRB. The panel assigns a score based on merit of the project. The final component is the MILCON TEAM FACTORS. They assign a score based on the project's support to various factors, e.g., efficiencies, mission timing, demolition, and overseas presence [Smith 1999]. Maximum score in this area is three.

Some differences between the Air Force and Army SEs are:

1. The Air Force SE applies to all MILCON projects whereas the Army SE applies only to revitalization projects.
2. The Air Force SE doesn't consider facility conditions.
3. The PRB equivalent (corporate panel) does not score as much.

B. TECHNIQUES FOR PROJECT SELECTION

The operations research literature documents many different techniques for project selection [Henricksen and Traynor 1999], such as:

1. Scoring
2. Goal programming or integer linear programming
3. Fuzzy logic
4. Analytic Network Process

The following sections review a few papers that employ the techniques mentioned above motivated by real-world project selection problems, but only one reports of a real-world application. In contrast, Newman et al [2000] contains numerous references to real-world applications for closely related optimization-based capital budgeting models. PESA shares several similarities with the above in this section including: multiple factors or criteria with an uncertain weighting scheme, output as a set of optimally funded projects, precedence with certain factors (in MACOM priority), and the ability for the decision maker to see the effects of each policy.

1. Scoring for Project Selection

Henricksen and Traynor [1999] develop equations to score research and development projects based on the criteria of relevance, risk, reasonableness, and return for the Los Alamos National Directed Research and Development Laboratory. Although they define their equations as algorithms, they amount to nothing more than simple scoring equations. They compute the value of a project as a function of cost and merit. By using an equation, they scale the project cost into a value between one and five. This scoring tool incorporates peer review team surveys to assess the merit of a project and is similar in approach to the military services' scoring equations by assigning weights to each criterion. Answers on the survey range from "very low" to "very high" which correspond to values one and five. Henricksen and Traynor [1999] developed a macro that allows a decision maker to carry out "what if" analysis by varying the inputs (similar to PESA); an improvement compared to the military services' SEs.

2. Goal Programming for Project Selection

We review three goal programming models for project selection with similar approaches to PESA.

Badri, Davis, and Davis [2001] attempt to explicitly incorporate the multiple factors affecting information system project selection through a zero-one goal programming model (the decision variables for project selection are zero-one). The objective function is to minimize the sum of the deviations from the goals that include benefits, hardware costs, software costs, risk factors, preferences of decision maker, and mandated requirements.

They apply the model to real world information system project selection (from a set of 28) for the Dubai Medical Center in the State of Dubai in the United Arab Emirates. After varying the ordering of the preferences for the projects' factors (similar to PESA), they assess the trade-offs by adjusting the target levels for the cost variables.

Kim and Emery [2000] are motivated by nine projects and two machine configurations over a four-year period for the Woodward Governor Company. Each decision variable (four for each project) represents the award options: award in 1998, 1999, 2000, or not at all. Management identified several goals to include in the model that represent both customer satisfaction and profit maximization.

The authors don't clearly define all of the variables. Although most of the model inputs are based on forecasts and projections, the model allows the decision maker to update it as information becomes available. This model also allows the decision maker to alter the ordering of the goals to conduct sensitivity analysis (similar to PESA).

The management of Woodward Governor Company chose to modify the results to accommodate other intangible factors not considered by the model (e.g., technological advancement or strategic movements made by Woodward's competitors during the implementation period).

Mukherjee and Bera [1995] apply goal programming to project selection for the Indian Mines Limited Coal Mining Company. Their model strives to select the most

suitable subset among eight mine projects (similar to PESA). They incorporate ratings from experts and executives to compute goal weights (similar to PESA). This model approach differs from the above goal programming models by using a probabilistic constraint for demand.

3. Fuzzy Logic for Project Selection

Machacha and Bhattacharya [2000] apply a fuzzy logic approach to project selection. The uncertainty of subjective judgment is present in the decision making process for project selection (similar to PESA). Decision making becomes difficult when information is incomplete.

The authors follow a series of steps:

- Decide what variables of the problem are relevant (similar to PESA).
- Describe those variables with adjectives that make sense (as if you were explaining it to another person).
- Form rules which describe the relationship between the results they want and the available data.

Based on these rules, the authors combine multiple criteria. According to the authors, other methods of project selection mostly ignore the behavior and backgrounds of decision makers. The authors apply their model to a hypothetical software product selection problem.

4. Analytic Network Process for Project Selection

Lee and Kim [2000] apply the analytic network process (ANP) within a zero-one goal programming model. The authors claim information system project selection is unique because interdependency among project criteria exists and the above methods are inadequate for information system project selection because they only consider independent criteria. Often times, the development of a related project creates a technical interdependence, e.g., software code developed by one project is used in the second project, then the total programming resources required by the second project are accordingly reduced.

ANP attempts to demonstrate the relationship, if any, among the criteria by identifying the criteria and determining to what degree of impact each has on the other. The authors obtain these answers with help from the decision maker. The information obtained from the ANP is then used to formulate a zero-one goal programming model as a weight [Lee and Kim 2000]. The authors fail to clearly demonstrate how to develop this weight.

Although PESA contains similarities to the above literature, it has some distinct differences. PESA is not a goal program. Instead of having penalties for deviations from constraints, PESA's constraints are either enforced or not enforced. Precedence is treated as a constraint. PESA allows the user to order priorities differently by enforcing constraints and choosing different values for constraint parameters.

THIS PAGE INTENTIONALLY LEFT BLANK

III. MODELING APPROACH

This chapter presents PESA, an integer linear program, to determine the best set of MILCON projects given various policies and budgets. PESA uses a spreadsheet provided by the ACSIM with the following information for each project:

- MACOM priority;
- ISR condition rating;
- ISR facility category type;
- PRB score;
- Whether or not a project has a synchronized arrival with a new mission;
- Whether or not a project uses design build;
- Whether or not a project demonstrates joint use potential; and
- Whether or not a project consolidates facilities, and eliminates relocatables, leased or temporary facilities.

In addition to the information above (more or less in order of importance based on the Army SE), cost (dollars) and project number are also provided. We develop our objective function and constraints based on the Army SE, Tamilin [2001a], and Van Antwerp [2001].

A. THE MODEL FORMULATION

This section defines the indices, sets, data, variables, and the formulation of the model.

1. Indices

p, p' Project

m MACOM

f ISR facility category {mission support, mobility, housing, community, installation support}

r ISR infrastructure condition rating {C4, C3,C2,C1}

2. Sets

P_m the set of all projects belonging to MACOM m.

$PJPR_m$ the set of project pairs p and p' where p' is funded only when p is funded for each MACOM m, for example,{(1,2), (2,3), (3,4) …}. This reflects MACOM priority.

CAT_f the set of all projects belonging to ISR facility category type f {e.g., all mission facility category type projects}.

RAT_r the set of all projects belonging to ISR condition rating r {e.g., all C4 ISR condition rating projects}.

$RCFC_{r,f}$ the set of all projects belonging to ISR condition rating r and ISR facility category type f {e.g., all projects with a C4 ISR condition rating in the mission facility category}.

$SYNC$ the set of all projects having a synchronized arrival with a new mission.

DB the set of all projects using design build.

JU the set of all projects having joint use potential.

C the set of all projects that either consolidate facilities, or eliminate relocatables, leased, or temporary facilities.

3. Data

$cost_p$ cost of project p [$M]

prb_p PRB score for project p [value]

$budget$ Available budget for revitalization MILCON projects [$M]

$\underline{macpj}_m$, $\overline{macpj}_m$ Desired minimum and maximum number of selected projects for each MACOM m {e.g., at least one project for each MACOM}.

$\underline{macbud}_m$, $\overline{macbud}_m$ Desired minimum and maximum fraction of the budget per MACOM m {e.g., TRADOC receives no more than 0.3 of the budget}.

$\underline{isrcat}_f$, $\overline{isrcat}_f$ Desired minimum and maximum fraction of the budget for ISR facility category f {e.g., at most 0.5 on ISR facility type housing}.

$\underline{isrrat}_r$, $\overline{isrrat}_r$ Desired minimum and maximum fraction of the budget for ISR rating r {e.g., at most 0.5 on ISR rating C3}.

$\underline{rcat}_{r,f}$, $\overline{rcat}_{r,f}$ Desired minimum and maximum fraction of the budget per ISR rating r in an ISR facility category f. {e.g., at least 0.6 on ISR rating C4 in facility type mission}.

$\underline{syncarr}$, $\overline{syncarr}$ Desired minimum and maximum fraction of the budget having a synchronized arrival with a new mission {e.g., at least 0.8 of the budget is allocated toward projects having a synchronized arrival with a new mission}.

$\underline{design}$,$\overline{design}$ Desired minimum and maximum fraction of the budget that use design build {e.g., at least 0.8 of the budget is allocated toward projects using design build}.

$\underline{jntuse}$, $\overline{jntuse}$ Desired minimum and maximum fraction of the budget having joint use potential {e.g., at least 0.8 of the budget is allocated toward projects having joint use potential}.

$\underline{confac}$, $\overline{confac}$ Desired minimum and maximum fraction of the budget that either consolidate facilities; or eliminates relocatables, leased or temporary facilities {e.g., at least 0.5 of the budget is allocated toward projects that consolidate facilities}.

4. Binary Variable

$SELECT_p$ 1 if project p is selected, 0 otherwise

5. Formulation

$$\max \sum_p prb_p \, SELECT_p \tag{1}$$

subject to:.

$$\sum_p cost_p \; SELECT_p \le budget \tag{2}$$

$$SELECT_p \le SELECT_{p'} \; \forall m(p, p') \in PJPR_m \tag{3}$$

$$\underline{macpj}_m \le \sum_{p \in Pm} SELECT_p \le \overline{macpj}_m \;\; \forall m \tag{4}$$

$$\underline{macbud}_m \; budget \le \sum_{p \in Pm} cost_p \, SELECT_p \le \overline{macbud}_m \; budget \;\; \forall m \tag{5}$$

$$\underline{isrcat}_f \; budget \le \sum_{p \in CATf} cost_p \, SELECT_p \le, \; \overline{isrcat}_f \; budget \;\; \forall f \tag{6}$$

$$\underline{isrrat}_r \, budget \le \sum_{p \in RATr} cost_p \, SELECT_p \le \overline{isrrat}_r \; budget \;\; \forall r \tag{7}$$

$$\underline{rcat}_{r,f} \; budget \le \sum_{p \in RCFC_{r,f}} cost_p \, SELECT_p \le \; \overline{rcat}_{r,f} \; budget \;\; \forall r, f \tag{8}$$

$$\underline{syncarr} \; budget \le \sum_{p \in SYNC} cost_p \, SELECT_p \le \overline{syncarr} \; budget \tag{9}$$

$$\underline{design} \; budget \le \sum_{p \in DB} cost_p \, SELECT_p \le \overline{design} \; budget \tag{10}$$

$$\underline{jntuse} \; budget \le \sum_{p \in JU} cost_p \, SELECT_p \le \overline{jntuse} \; budget \tag{11}$$

$$\underline{confac} \; budget \le \sum_{p \in C} cost_p \; SELECT_p \le \overline{confac} \; budget \tag{12}$$

$SELECT_p$ binary $\forall p$ (13)

a. The Objective Function

The objective function, equation (1), attempts to obtain the highest total PRB score.

b. Budget Constraint

Equation (2) ensures the total cost of the selected projects does not violate the allocated budget for MILCON projects.

c. MACOM Constraints

By selection of project pairs in $PJPR_m$, equation (3) maintains MACOM priority integrity. For example, TRADOC's priority three won't be selected before their number two priority. Equation (4) establishes the lower and upper bound on the number of projects for each MACOM. Equation (5) enforces the lower and upper bound on the fraction of the budget allocated per MACOM.

d. ISR Constraints

Equation (6) establishes the lower and upper bound on the fraction of the budget allocated for each ISR facility category. Equation (7) establishes the lower and upper bound on the fraction of the budget allocated for each ISR rating. Equation (8) establishes the lower and upper bound on the fraction of the budget allocated for each ISR condition rating in an ISR facility category.

e. Other Factor Constraints

Equation (9) establishes the lower and upper bound on the desired fraction of the budget allocated toward projects that are synchronized with the arrival of a new mission. Equation (10) establishes the lower and upper bound on the desired fraction of the budget allocated towards projects using design build. Equation (11) establishes the lower and upper bound on the desired fraction of the budget allocated toward projects demonstrating joint use potential. Equation (12) establishes the lower and upper bound

on the fraction of the budget allocated toward projects that consolidate facilities; eliminates relocatables, leased or temporary facilities. Equation (13) ensures the decision variable is binary.

The following equation name listing corresponds to the above equation numbers for use in Chapter IV:

(1) MAXPRB
(2) BUDGET
(3) MACPRI
(4) MACPJ
(5) MACBUD
(6) CRATE
(7) ICAT
(8) CRATECAT
(9) SA
(10) DB
(11) JU
(12) CF
(13) BINVAR

IV. COMPUTATIONAL RESULTS

This chapter provides background on data sources, approach, and results by using PESA. Specifically, PESA evaluates and selects the best set of MILCON projects under various policies and budgets for the set of 62 projects considered by the ACSIM in 2001. The policies reflect the most important aspects of Army MILCON as mentioned in Chapters I and II. With the benefit of hindsight, we evaluate and select these projects using a budget of $600M (the actual amount allocated in 2001) as well as other budget parameters. In particular, we believe PESA could have helped justify a $700M budget in 2001 as supported by our analysis. Although we conduct many PESA runs, we provide a subset of the results (mostly for $600M) that implement various policies and available budgets.

We answer questions such as:

1. What projects are selected when enforcing different budgets and MACOM priority?
2. What projects are selected when enforcing budget, MACOM priority, and requiring funding of all C3 and C4 projects?
3. What projects are selected if we enforce MACOM priority for the first three projects?

PESA is implemented using a personal computer equipped with a Pentium IV 2.00 GHZ processor using GAMS Rev 117 [GAMS Development Corp. 2001] with the CPLEX 6.6.1 [ILOG Corporation 2002] solver. XLLINK software [Rutherford and Maliyev 2002] provides the spreadsheet interface between GAMS and Microsoft Excel 2000® [Microsoft Corp. 1999] input and output files. PESA's run time varies, but is always less than one minute.

A. DATA SOURCES

The ACSIM provides the fiscal year 2001 PRB project data in an Excel Spreadsheet and the budget amount of $600 million. Tables 8, 9, 10 and 11 provide a summary of the project data.

MACOM	Dollars Requested ($M)	Number of Projects Requested	Fraction of Budget Requested	Fraction of Projects Requested	Average Cost of Project ($M)
AMC	97.9	7	0.16	0.11	14.0
ATEC	15.2	3	0.03	0.05	5.1
CID	3.7	2	0.01	0.03	1.9
DAR	9.4	1	0.02	0.02	9.4
EUSA	20.9	3	0.03	0.05	7.0
FORSCOM	97.2	10	0.16	0.16	9.7
INSCOM	35.1	2	0.06	0.03	17.6
MDW	215.5	5	0.36	0.08	43.1
MEDCOM	12.3	3	0.02	0.05	4.1
MEPCOM	15.0	2	0.03	0.03	7.5
MTMC	2.7	1	0.00	0.02	2.7
TRADOC	101.6	4	0.17	0.06	25.4
USAREC	12.0	2	0.02	0.03	6.0
USAREUR	50.9	6	0.08	0.10	8.5
USARPAC	183.7	9	0.31	0.15	20.4
USMA	98.0	2	0.16	0.03	49.0
Totals	970.8	62	1.62	1.00	15.7

Table 8. Data Summary by MACOM

By MACOM, the dollars requested and the number of projects requested vary substantially. For example, MDW requests $215.5M, while MTMC requests $2.7M and FORSCOM requests 10 projects, while MTMC requests 1 project.

C-Rating	Dollars Requested ($M)	Number of Projects Requested	Fraction of Budget Requested	Fraction of Projects Requested	Average Cost of Project ($M)
4	427.9	32	0.71	0.52	13.4
3	283.0	16	0.47	0.26	17.7
2	52.2	6	0.09	0.10	8.7
1	207.8	8	0.35	0.13	26.0
Totals	970.8	62	1.62	1.00	15.7

Table 9. Data Summary by ISR Condition Rating

The 48 projects in the ISR condition rating C3 and C4 comprise the majority of the total projects requested (32 + 16) and dollars requested ($427.9M + $283.0M). Using a budget of $600M, the Army cannot fund all C3 and C4 projects.

Facility Category	Dollars Requested ($M)	Number of Projects Requested	Fraction of Budget Requested	Fraction of Projects Requested	Average Cost of Project ($M)
Mission Support	706.7	38	1.18	0.61	18.6
Mobility	85.0	3	0.14	0.05	28.3
Housing	7.3	1	0.01	0.02	7.3
Community	68.6	12	0.11	0.19	5.7
Installation Support	103.3	8	0.17	0.13	12.9
Totals	970.8	62	1.62	1.00	15.7

Table 10. Data Summary by ISR Facility Category Type

The 38 projects in the mission support ISR facility category comprise the majority of the total projects requested and dollars requested ($706.7M). For example, if all mission support projects are funded, they require 1.18 of the available budget. The mission support projects account for 0.61 of all the projects requested with an average cost of $18.6M.

Facility Category	C-Rating	Dollars Requested ($M)	Number of Projects Requested	Fraction of Budget Requested	Fraction of Projects Requested	Average Cost of Project ($M)
Mission Support	4	337.0	20	0.56	0.32	16.8
	3	124.2	8	0.21	0.13	15.5
	2	47.9	4	0.08	0.06	12.0
	1	197.7	6	0.33	0.10	32.9
Mobility	4	7.6	1	0.01	0.02	7.6
	3	77.4	2	0.13	0.03	38.7
	2	0.0	0	0.00	0.00	0.0
	1	0.0	0	0.00	0.00	0.0
Housing	4	0.0	0	0.00	0.00	0.0
	3	7.3	1	0.01	0.02	7.3
	2	0.0	0	0.00	0.00	0.0
	1	0.0	0	0.00	0.00	0.0
Community	4	34.3	6	0.06	0.10	5.7
	3	21.6	3	0.04	0.05	7.2
	2	2.7	1	0.00	0.02	2.7
	1	10.1	2	0.02	0.03	5.1

Facility Category	C-Rating	Dollars Requested ($M)	Number of Projects Requested	Fraction of Budget Requested	Fraction of Projects Requested	Average Cost of Project ($M)
Installation Support	4	49.1	5	0.08	0.08	9.8
	3	52.6	2	0.09	0.03	26.3
	2	1.6	1	0.00	0.02	1.6
	1	0.0	0	0.00	0.00	0.0
Totals		970.8	62	1.62	1.00	15.7

Table 11. Data Summary by ISR Facility Category Type and Condition Rating

The C4 mission support projects total $337.0M, which if all are funded, require 0.56 of the available budget. This makes sense that many projects requests are for facilities in the worst condition (ISR condition rating C4) and the most important facility type (ISR facility category mission support). The C4 mission support projects account for 0.32 of all projects requested with an average cost of $16.8M.

The PRB scores range from 1.36 to 4.34. Figure 1 shows the frequency of the occurrences of the PRB scores in the given ranges. The majority of the PRB scores are between 2.00 and 3.49.

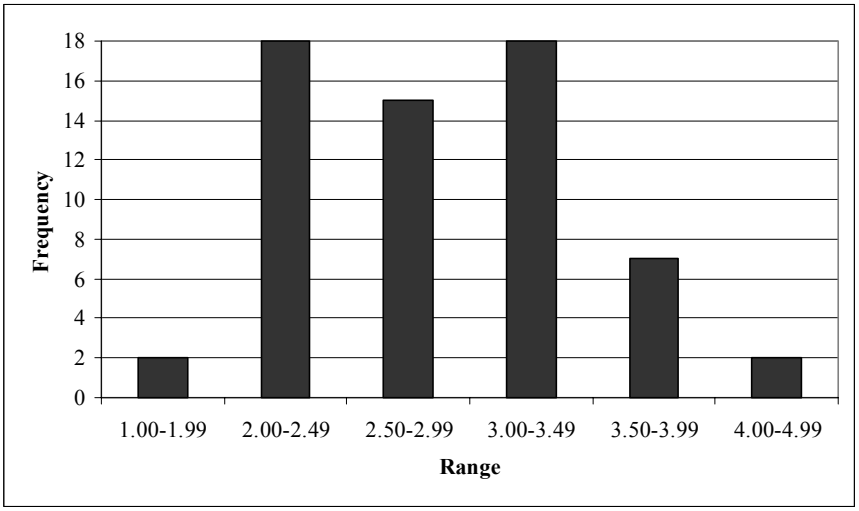

Figure 1. PRB Score Distribution

Tables 12, 13, 14, and 15 summarize data about other important Army MILCON factors:

- Whether or not a project has a synchronized arrival with a new mission.
- Whether or not a project uses design build.
- Whether or not a project has joint use potential.
- Whether or not a project consolidates facilities; eliminates relocatables, leased or temporary facilities.

MACOM	Dollars Requested ($M)	Number of Projects Requested	Fraction of Budget Requested	Fraction of Projects Requested	Average Cost of Project ($M)
AMC	0.0	0	0.00	0.00	0.0
ATEC	0.0	0	0.00	0.00	0.0
CID	0.0	0	0.00	0.00	0.0
DAR	0.0	0	0.00	0.00	0.0
EUSA	10.7	2	0.02	0.03	5.4
FORSCOM	45.4	5	0.08	0.08	9.1
INSCOM	0.0	0	0.00	0.00	0.0
MDW	5.0	1	0.01	0.02	5.0
MEDCOM	0.0	0	0.00	0.00	0.0
MEPCOM	0.0	0	0.00	0.00	0.0
MTMC	0.0	0	0.00	0.00	0.0
TRADOC	13.4	2	0.02	0.03	6.7
USAREC	0.0	0	0.00	0.00	0.0
USAREUR	0.0	0	0.00	0.00	0.0
USARPAC	0.0	0	0.00	0.00	0.0
USMA	0.0	0	0.00	0.00	0.0
Totals	74.5	10	0.12	0.16	7.4

Table 12. Data Summary of Synchronized Arrival Projects

There are relatively few synchronized arrival projects. For example, EUSA has two projects that are a synchronized arrival with a new mission. The synchronized arrival projects for EUSA total $10.7M, which if all are funded, require 0.02 of the available budget. The synchronized arrival projects for EUSA account for 0.03 of all projects requested with an average cost of $5.4M.

MACOM	Dollars Requested ($M)	Number of Projects Requested	Fraction of Budget Requested	Fraction of Projects Requested	Average Cost of Project ($M)
AMC	90.6	6	0.15	0.10	15.1
ATEC	15.2	3	0.03	0.05	5.1
CID	3.7	2	0.01	0.03	1.9
DAR	0.0	0	0.00	0.00	0.0
EUSA	20.9	3	0.03	0.05	7.0
FORSCOM	68.0	7	0.11	0.11	9.7
INSCOM	35.1	2	0.06	0.03	17.6
MDW	13.5	3	0.02	0.05	4.5
MEDCOM	12.3	3	0.02	0.05	4.1
MEPCOM	8.2	1	0.01	0.02	8.2
MTMC	0.0	0	0.00	0.00	0.0
TRADOC	101.6	4	0.17	0.06	25.4
USAREC	12.0	2	0.02	0.03	6.0
USAREUR	21.7	4	0.04	0.06	5.4
USARPAC	118.7	8	0.20	0.13	14.8
USMA	49.0	1	0.08	0.02	49.0
Totals	570.3	50	0.95	0.79	11.4

Table 13. Data Summary of Design Build Projects

If funded, almost all projects (50 out of 62) use design build; design build allows the Army to have one contractor responsible for the entire project [Assistant Chief of Staff for Installation Management 2002b]. The other option (viewed as unfavorable) is design bid build where the Army has a contractor for each part of the project [Assistant Chief of Staff for Installation Management 2002b].

MACOM	Dollars Requested ($M)	Number of Projects Requested	Fraction of Budget Requested	Fraction of Projects Requested	Average Cost of Project ($M)
AMC	94.8	6	0.16	0.10	15.8
ATEC	15.2	3	0.03	0.05	5.1
CID	3.7	2	0.01	0.03	1.9
DAR	0.0	0	0.00	0.00	0.0
EUSA	20.9	3	0.03	0.05	7.0
FORSCOM	97.2	10	0.16	0.16	9.7
INSCOM	30.0	1	0.05	0.02	30.0
MDW	215.5	5	0.36	0.08	43.1
MEDCOM	0.0	0	0.00	0.00	0.0
MEPCOM	6.8	1	0.01	0.02	6.8

MACOM	Dollars Requested ($M)	Number of Projects Requested	Fraction of Budget Requested	Fraction of Projects Requested	Average Cost of Project ($M)
MTMC	2.7	1	0.00	0.02	2.7
TRADOC	101.6	4	0.17	0.06	25.4
USAREC	12.0	2	0.02	0.03	6.0
USAREUR	39.0	4	0.07	0.06	9.8
USARPAC	131.6	7	0.22	0.11	18.8
USMA	98.0	2	0.16	0.03	49.0
Totals	868.8	52	1.45	0.82	16.6

Table 14. Data Summary of Joint Use Projects

Almost all projects demonstrate joint use potential (52 out of 62).

MACOM	Dollars Requested ($M)	Number of Projects Requested	Fraction of Budget Requested	Fraction of Projects Requested	Average Cost of Project ($M)
AMC	74.3	5	0.12	0.08	14.9
ATEC	0.0	0	0.00	0.00	0.0
CID	1.7	1	0.00	0.02	1.7
DAR	0.0	0	0.00	0.00	0.0
EUSA	10.7	2	0.02	0.03	5.4
FORSCOM	67.9	7	0.11	0.11	9.7
INSCOM	0.0	0	0.00	0.00	0.0
MDW	142.5	3	0.24	0.05	47.5
MEDCOM	10.3	2	0.02	0.03	5.1
MEPCOM	0.0	0	0.00	0.00	0.0
MTMC	0.0	0	0.00	0.00	0.0
TRADOC	13.4	2	0.02	0.03	6.7
USAREC	12.0	2	0.02	0.03	6.0
USAREUR	21.6	3	0.04	0.05	7.2
USARPAC	0.0	0	0.00	0.00	0.0
USMA	0.0	0	0.00	0.00	0.0
Totals	354.3	28	0.59	0.44	12.8

Table 15. Data Summary of Consolidated Facilities Projects

Only 28 projects consolidate facilities.

B. OVERVIEW OF PESA'S RESULTS

We conduct four different PESA excursions that significantly alter available budget and policies. Within each excursion, we implement a number of PESA runs that maintain the same objective function (MAXPRB) and decision variable (BINVAR), but vary the level of adherence to other constraints. In this way, PESA allows the user to input the policies, defined by the level of adherence to constraints.

The first excursion is called full, the second excursion (MACOM priority relaxed) differs from the full excursion by only adhering to MACOM priority for the first three projects (e.g., once FORSCOM's first three projects are selected, then its other projects do not have to adhere to MACOM priority), the third excursion (changing budget) differs from the full excursion by changing the available budget ($700M, $500M, and $400M), and the fourth excursion focuses on unlimited budget with certain constraints (budget request).

C. RESULTS FROM THE EXCURSIONS

In these sections, we present a subset of PESA's results from the four excursions listing only the constraints and parameters used.

1. Full, MACOM Priority Relaxed, and Changing Budget Excursions

Table 16 provides a summary of the most interesting PESA results. Shown are statistics on eleven different recommended sets of projects to fund. The first recommended option called base uses constraints BUDGET and MACOMPRI. We extensively compare the base recommendation to recommendation options 1 to 4 (from the full excursion) that add constraints to develop improved funding options. We then compare recommended options 5-7 from the MACOM priority relaxed excursion to the corresponding recommended options 2-4 to determine if relaxing MACOM priority produce better results. Recommended options 8-10 demonstrate results from the changing budget excursion (budgets set equal to $700M, $500M, and $400M respectively).

Recommended Option	Projects selected (not)	Budget Required ($M)	Average Project Funded Cost ($M) (not)	Average PRB score (not)	Number of C3 and C4 funded (not)	Fraction of C3 and C4 Projects Funded (not)	Fraction of C3 and C4 Projects Funded in Dollars (not)	Fraction of Budget Spent on C3 and C4 Projects (not)	Number of mission and mobility funded (not)	Fraction of Mission and Mobility Projects Funded (not)	Fraction of Mission and Mobility Projects Funded in Dollars (not)	Fraction of Budget Spent on Mission and Mobility Projects (not)	Highest MACOM Priority Not Funded	OBJ Function Value	Observations
Base	52 (10)	563.5	10.8 (40.7)	3.02 (2.19)	38 (9)	0.813 (0.187)	0.616 (0.384)	0.729 (0.271)	35 (6)	0.854 (0.146)	0.533 (0.467)	0.703 (0.297)	USMA 1, USARPAC 3	157.15	High cost projects not selected
1	50 (12)	599.2	12.0 (31.0)	2.95 (2.63)	41 (7)	0.854 (0.146)	0.760 (0.240)	0.901 (0.099)	32 (9)	0.780 (0.220)	0.568 (0.432)	0.750 (0.250)	AMC 1	147.48	High fraction of budget spent on C3 and C4; and mission and mobility
2	44 (18)	594.2	13.5 (20.9)	3.02 (2.57)	35 (13)	0.729 (0.271)	0.689 (0.311)	0.817 (0.183)	30 (11)	0.732 (0.268)	0.636 (0.364)	0.840 (0.160)	ATEC 1	132.07	Low number of projects selected
3	48 (14)	580.8	12.1 (27.9)	3.04 (2.35)	38 (10)	0.792 (0.208)	0.651 (0.349)	0.772 (0.228)	31 (10)	0.756 (0.244)	0.555 (0.445)	0.732 (0.268)	USMA 2	146.06	High fraction of budget spent on C3 and C4; and mission and mobility
4	43 (19)	599.4	13.9 (19.6)	3.08 (2.45)	34 (14)	0.708 (0.292)	0.708 (0.292)	0.839 (0.161)	28 (13)	0.683 (0.317)	0.636 (0.364)	0.839 (0.161)	INSCOM, MEDCOM 2	132.37	Low number of projects selected
5	46 (16)	598.9	13.0 (23.2)	3.02 (2.50)	37 (11)	0.771 (0.229)	0.696 (0.304)	0.825 (0.175)	32 (9)	0.780 (0.220)	0.642 (0.358)	0.848 (0.152)	ATEC 1	139.07	High fraction of budget spent on C3 and C4; and mission and mobility
6	53 (9)	599.5	11.3 (41.3)	2.96 (2.48)	42 (6)	0.875 (0.125)	0.675 (0.325)	0.800 (0.200)	33 (8)	0.805 (0.195)	0.548 (0.452)	0.723 (0.277)	USMA 2	156.67	High fraction of budget spent on C3 and C4
7	46 (16)	600.0	13.0 (23.2)	3.05 (2.42)	34 (14)	0.708 (0.292)	0.676 (0.324)	0.801 (0.199)	31 (10)	0.756 (0.244)	0.642 (0.358)	0.847 (0.153)	MEPCOM 2	140.27	High fraction of budget spent on C3 and C4; and mission and mobility
8	57 (5)	696.8	12.2 (54.8)	2.96 (2.07)	44 (4)	0.917 (0.083)	0.803 (0.197)	0.816 (0.184)	37 (4)	0.902 (0.098)	0.671 (0.329)	0.759 (0.241)	USMA 2	168.68	High fraction of budget spent on C3 and C4; and mission and mobility
9	46 (16)	498.6	10.8 (29.5)	3.09 (2.31)	33 (15)	0.688 (0.312)	0.524 (0.476)	0.745 (0.255)	31 (10)	0.732 (0.268)	0.505 (0.495)	0.800 (0.200)	USMA 2	142.01	High fraction of budget spent on C3 and C4; and mission and mobility
10	35 (27)	399.7	11.4 (21.2)	3.12 (2.59)	27 (21)	0.563 (0.437)	0.454 (0.546)	0.807 (0.193)	21 (20)	0.512 (0.488)	0.392 (0.608)	0.775 (0.225)	USARPAC, USMA 2	109.18	High fraction of budget spent on C3 and C4; and mission and mobility

Table 16. Results from Excursion Full, MACOM Priority Relaxed, and Changing Budget

This table shows detailed information on options that have comparative strengths and weaknesses. For example, the detailed information on PESA's recommended option one indicates the selection of 50 projects (12 not selected). Budget required to fund those 50 projects is $599.2M with an average project cost of $12.0M (average cost of $31.0M for projects not selected). Selected projects' average PRB score is 2.95 (not selected is 2.63). Number of C3 and C4 projects selected is 41 (not selected 7). Of C3 and C4 projects requested, 0.854 are selected (0.146 not selected). C3 and C4 projects selected fund 0.760 of the dollars required to fund all C3 and C4 projects (projects not selected account for 0.240). Fraction of the budget spent on C3 and C4 projects is 0.901 (0.099 spent on projects in other ratings), etc.

Below are the specifics of each recommended option, listing only the enforced constraints and parameters used. We develop the parameters from the data summary to demonstrate PESA. The main difference in each option occurs in what other constraints are enforced to specifically develop policies.

Recommended Option BASE (Table 16) funds based only on budget and MACOM priority (enforce BUDGET and MACPRI). Although the objective function is high, the fraction of the budget spent on C3 and C4 projects is relatively low (0.729). This option also satisfies constraints on the upper bound for ICAT and upper bound for MACBUD.

Recommended Option 1 (Table 16) funds with consideration to the ISR condition rating. We enforce BUDGET, lower and upper bound for CRATE, and MACPRI.

The parameters for $\underline{isrrat}_r$ are set equal to 0.60, 0.20, 0.02, and 0 for r equal to C4, C3, C2, and C1 respectively. The parameters for $\overline{isrrat}_r$ are set equal to 1, 1, 0.10, and 0.10 for r equal to C4, C3, C2, and C1 respectively.

As expected, adding a lower and upper bound for CRATE increases the fraction of budget spent on C3 and C4 projects (0.901). A possible downside is AMC doesn't receive any projects. This option also satisfies some other constraints e.g., upper bound for MACBUD and upper bound for ICAT.

Recommended Option 2 (Table 16) funds with consideration to the ISR condition rating in an ISR facility category type. We enforce BUDGET, lower and upper bound on CRATECAT, and MACPRI.

The parameters for $\underline{rcat}_{r,f}$ and $\overline{rcat}_{r,f}$ where r is equal to C4, C3, C2, and C1 respectively and f is equal to mission support, mobility, housing, community, installation support respectively are in Table 17.

	C4 [lower, upper]	C3 [lower, upper]	C2 [lower, upper]	C1 [lower, upper]
Mission support	0.450, 0.750	0.150, 0.500	0.000, 0.250	0.000, 0.100
Mobility	0.005, 0.700	0.100, 0.450	0.000, 0.200	0.000, 0.100
Housing	0.000, 0.650	0.005, 0.400	0.000, 0.150	0.000, 0.050
Community	0.050, 0.600	0.050, 0.350	0.000, 0.100	0.000, 0.050
Installation support	0.050, 0.550	0.020, 0.300	0.000, 0.100	0.000, 0.050

Table 17. Parameters for $\underline{rcat}_{r,f}$ and $\overline{rcat}_{r,f}$ (Budget \$600M)

The first column is the ISR facility category *f*. The first row is the ISR condition rating *r* with the lower and upper bound. For example, where *r* is equal to C4 and *f* is equal to mission support $\underline{rcat}_{r,f}$ is set equal to 0.0450 and $\overline{rcat}_{r,f}$ is set equal to 0.750.

The results indicate an improvement in budget spent on C3 and C4 projects (0.817) as well as in mission support and mobility (0.840). The only downside is the number of projects selected is low (44). This option also satisfies some other constraints e.g., lower bound for DB and lower bound for CF.

Recommended Option 3 (Table 16) funds with consideration to the MACOMs and ISR condition rating in an ISR facility category type. We enforce BUDGET, lower and upper bound for MACBUD, upper bound for CRATECAT, and MACPRI.

The parameters for $\underline{macbud}_m$ are set equal to 0.0001 for $\forall m$ and $\overline{macbud}_m$ are set equal to 0.25 for $\forall m$ (see recommended option two for $\overline{rcat}_{r,f}$).

Although this policy improves the fraction of the budget allocated to C3 and C4 projects (0.772) and the fraction of the budget spent on mission and mobility projects (0.732), the entire budget is not spent (\$580.8M); resulting in remaining projects that could be funded, but would violate MACOM priority. This option also satisfies some other constraints e.g., lower bound for SA and lower bound for CF.

Recommended Option 4 (Table 16) funds with consideration to the MACOMs, ISR facility category type, the ISR condition rating, synchronized arrival, design build, joint use, and consolidate facilities. We enforce BUDGET, lower and upper bound for

ICAT, lower bound for CRATE, lower and upper bound for MACBUD (see recommended option three), MACOMPRI, lower bound for SA, lower bound DB, lower bound for JU, and lower bound for CF.

The parameters for $\underline{isrcat}_f$ are set equal to 0.70, 0.10, 0.001, 0.05, 0.05 for f equal to mission support, mobility, housing, community, and installation support respectively, $\overline{isrcat}_f$ are set equal to 0.80, 0.40, 0.30, 0.20, 0.20 for f equal to mission support, mobility, housing, community, and installation support respectively, and $\underline{isrrat}_r$ are set equal to 0.60, 0.20, 0.02, and 0 for r equal to C4, C3, C2, and C1 respectively; $\underline{syncarr}$ is set equal to 0.10, $\underline{design}$ is set equal to 0.50, $\underline{jntuse}$ is set equal to 0.40, and $\underline{confac}$ is set equal to 0.20 (see recommended option three for parameters for $\underline{macbud}_m$ and $\overline{macbud}_m$).

The fraction of the budget spent on C3 and C4 projects (0.839), mission support and mobility (0.839), and each MACOM receiving at least one project are improvements. The only downside is the low number of projects selected (43).

Recommended Options 5-7 correspond to the same policies and parameters as 2-4, except MACOM priority is enforced for only the first three projects (MACOM priority relaxed excursion).

Recommended Option 5 (Table 16) funds with consideration to the MACOMs and the ISR condition rating in an ISR facility category type. We enforce BUDGET, lower and upper bound for CRATECAT, and MACPRI (relaxed).

Relaxing the MACOM priority produces an improvement in the results compared to option two. However, possible downsides are the number of projects is still low (46) and ATEC doesn't receive any projects. This option also satisfies some other constraints e.g., upper bound for MACBUD and lower bound for DB.

Recommend Option 6 (Table 16) funds with consideration to the MACOMs and ISR condition rating in an ISR facility category type. We enforce BUDGET, lower and upper bound for MACBUD, upper bound for CRATECAT, and MACPRI (relaxed).

Compared to recommended option three, this policy results in an improvement in the fraction of budget spent on C3 and C4 projects (0.800) and in the fraction of the budget spent on mission support and mobility (0.723). This policy also results in a high number of projects funded (53) and also satisfies some other constraints e.g., lower bound for CRATE and lower bound for SA.

Recommended Option 7 (Table 16) funds with consideration to the MACOMs, ISR facility category type, ISR condition rating, synchronized arrival, design build, joint use, and consolidate facilities. We enforce BUDGET, lower and upper bound for MACBUD, lower and upper bound for ICAT, lower bound for CRATE, MACOMPRI (relaxed), lower bound for SA, lower bound DB, lower bound for JU, and lower bound for CF.

Relaxing the MACOM priority produces an improvement in the results compared to number four. The fraction of budget spent on C3 and C4 projects (0.801) and the fraction of the budget spent of mission support and mobility projects (0.847) increases. The only downside is the number of projects selected (46).

Recommended Option 8 (Table 16) funds with consideration to the MACOMs, ISR facility category type, synchronized arrival, design build, joint use, and consolidate facilities. We enforce BUDGET ($700M), lower and upper bound for MACBUD, upper bound for ICAT, MACPRI, lower bound for SA, lower bound for DB, lower bound for JU, and lower bound for CF.

The parameters for $\overline{isrcat}_f$ are set equal to 0.80, 0.40, 0.30, 0.20, and 0.20 for f equal to mission support, mobility, housing, community, and installation support respectively, $\underline{macbud}_m$ are set equal to 0.0001 for $\forall m$, $\overline{macbud}_m$ are set equal to 0.25

for $\forall m$; $\underline{syncarr}$ is set equal to 0.10, $\underline{design}$ is set equal to 0.50, $\underline{jntuse}$ is set equal to 0.40, and $\underline{confac}$ is set equal to 0.20. The fraction of budget spent on C3 and C4 projects (0.816) and on mission support and mobility (0.759) is high. This option satisfies only one other constraint; the upper bound for CRATECAT.

Recommended Option 9 (Table 16) funds with consideration to the MACOMs, the ISR condition rating in an ISR facility category type, synchronized arrival, design build, joint use, and consolidate facilities. We enforce BUDGET ($500M), lower and upper bound for MACBUD, upper bound for CRATECAT, MACPRI, lower bound for SA, lower bound for DB, lower bound for JU, and lower bound for CF.

The parameters for $\overline{rcat}_{r,f}$ where r is equal to C4, C3, C2, and C1 and f is equal to mission support, mobility, housing, community, installation support respectively are in Table 18, $\underline{macbud}_m$ are set equal to 0.0001 for $\forall m$, $\overline{macbud}_m$ are set equal to 0.25 for $\forall m$; $\underline{syncarr}$ is set equal to 0.10, $\underline{design}$ is set equal to 0.40, $\underline{jntuse}$ is set equal to 0.30, and $\underline{confac}$ is set equal to 0.20.

	C4	C3	C2	C1
Mission support	0.750	0.500	0.250	0.250
Mobility	0.700	0.450	0.200	0.100
Housing	0.650	0.400	0.150	0.050
Community	0.600	0.350	0.100	0.050
Installation support	0.550	0.300	0.100	0.050

Table 18. Parameters for $\overline{rcat}_{r,f}$ (Budget $500M)

The first column is the ISR facility category f. The first row is the ISR condition rating r. For example, where r is equal to C4 and f is equal to mission support $\overline{rcat}_{r,f}$ is set equal to 0.750.

Although the budget is reduced, the fraction of budget spent on C3 and C4 projects (0.745) and on mission support and mobility (0.800) is high. This option also satisfies some other constraints e.g., upper and lower bound for ICAT.

Recommended Option 10 (Table 16) funds with consideration to the MACOMs, the ISR facility category type, synchronized arrival, design build, joint use, and consolidate facilities. We enforce BUDGET ($400M), lower and upper bound for MACBUD, upper bound for ICAT, MACPRI, lower bound for SA, lower bound for DB, lower bound for JU, and lower bound for CF.

The parameters for $\overline{isrcat}_f$ are set equal to 0.80, 0.40, 0.30, 0.20, 0.20 for f equal to mission support, mobility, housing, community, and installation support respectively, $\underline{macbud}_m$ are set equal to 0.0001 for $\forall m$, $\overline{macbud}_m$ are set equal to 0.25 for $\forall m$; $\underline{syncarr}$ is set equal to 0.20, $\underline{design}$ is set equal to 0.40, $\underline{jntuse}$ is set equal to 0.30, and $\underline{confac}$ is set equal to 0.20.

Although the budget is reduced, the fraction of budget spent on C3 and C4 projects (0.807) and on mission support and mobility (0.775) is high. This option also satisfies some other constraints e.g., upper and lower bound for CRATE.

2. Budget Request Excursion

For the budget request excursion we conduct six PESA runs to answer the question of, "How much money do we need to accomplish certain goals?" Table 19 summarizes the results from a subset of these goals.

Budget Requirement	Budget Required Without Any MACOM Priority Restriction ($M)	Budget Required to Satisfy the Constraints ($M)
1	710.9	820.1
2	710.9	819.2
3	791.7	970.8
4	791.7	920.4
5	546.2	770.2
6	546.2	768.8

Table 19. Summary of Budget Requests Excursion

Shown is the budget recommended to enforce strict adherence to six policies (budget requirement). For example, budget requirement 1 must fund all C3 and C4 projects. It requires $710.9M if there is no adherence to MACOM priority; however it requires $820.1M to fund all C3 and C4 projects while adhering to MACOM priority.

Budget requirement descriptions with these goals are:

1. Fund all ISR condition rating C3 and C4 projects and enforce MACOM priority.
2. Fund all ISR condition rating C3 and C4 projects and enforce MACOM priority for first three only.
3. Fund all ISR facility category type mission support and mobility projects and enforce MACOM priority.
4. Fund all ISR facility condition type mission support and mobility projects and enforce MACOM priority for first three only.
5. Fund all ISR condition rating C3 and C4 projects in ISR facility category mission support and mobility and enforce MACOM priority.
6. Fund all ISR condition rating C3 and C4 projects in ISR facility category mission support and mobility and enforce MACOM priority for first three only.

In all of the above budget requirements, enforcing the MACOM priority requires significantly more dollars to accomplish these goals.

3. Comparison to Army SE

In this section we compare PESA's recommended Option 1 from above to the Army SE (Table 20).

	Number of Projects Selected	Number of Projects Selected the Other Did Not	Fraction of Budget Spent on C3 and C4	Fraction of Budget Spent on Mission and Mobility	Highest MACOM Priority Not Funded
PESA	50	11	0.901	0.750	AMC 1
SE	44	5	0.840	0.765	AMC 3

Table 20. PESA and SE Results Comparison

PESA recommends a set of projects that spends more of the budget on C3 and C4 projects.

Because the project score from the SE relies heavily on the MACOM priority, many projects are selected in an order where each MACOM receives its number one priority; then, each MACOM receives its second priority, etc. The SE results in MACOMs with few projects requested (typically smaller MACOMs by number of installations), receiving all projects and MACOMs with more project requests (generally larger MACOMs by number of installations) not allowing lower priority projects much

consideration. For example, five ISR condition rating C3 and C4 projects in the ISR facility category type mission are not selected. Although the SE funds some of the worst condition facilities, some MACOMS (typically larger) are not receiving a needed portion of the budget to improve their facilities.

PESA doesn't select AMC's number one priority because of high cost ($42.0M) and it is an ISR condition rating C1.

THIS PAGE INTENTIONALLY LEFT BLANK

V. CONCLUSION AND FUTURE RESEARCH

A. CONCLUSION

The Vice Chief of Staff of the Army, GEN Keane, requested ACSIM develop a more scientific process to select Army MILCON projects [Tamilin 2001b]. Although the Army developed a scoring equation, the ACSIM wanted an improved way to accomplish GEN Keane's request [Tamilin 2001a]. PESA uses data verified and accepted by ACSIM to select and evaluate MILCON projects. PESA allows the user to change inputs to reflect policies which assist in recommending sets of projects for funding.

B. FUTURE RESEARCH

As mentioned in Chapter I, we have only focused on revitalization MILCON projects. It is also possible that PESA could be modified to evaluate Army Facility Strategy (AFS) projects.

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF REFERENCES

Assistant Chief of Staff for Installation Management, "ACSIM's Installation Status Report Website",(U)http://isr.pentagon.mil, January 2002a.

Assistant Chief of Staff for Installation Management, "Assistant Chief of Staff for Installation Management",(U) http://www.hqda.army.mil/acsimweb, January 2002b.

Badri, B.A., Davis, D. and Davis, D., "A Comprehensive 0-1 Goal Programming Model for Project Selection", *International Journal of Project Management,* v.19, i. 4, 2001.

Bridges, M., *Optimally Funding Army Installation repair and Maintenance Activities*, Operations Research Masters Thesis, Naval Postgraduate School, Monterey, CA, September 1997.

Brooke, A., Kendrick, D., Meeraus, A., and Raman, R., GAMS, A User's Guide, Release 2.50, The Scientific Press, San Francisco, CA, 1998.

DAIM-FD policy memo dated 14 July 2000 subject: Utilization of Design Build Procurement Strategy.

Fasolo, A., Information Paper, "The Installation Status Report-2001", Construction Division, Office of the Assistant Chief of Staff for Installation Management, March 2001.

Federal Facilities Council Technical Report No. 142, *Sustainable Federal Facilities, A Guide to Integrating Value Engineering, Life-Cycle Costing, and Sustainable Development*, The Federal Facilities Council Ad Hoc Task Group on Integrating Sustainable Design, Life-Cycle Costing, and Value Engineering into Facilities Acquisition, p1-6, 2001.

GAMS Development Corporation, *General Algebraic Modeling System (GAMS) Rev 117 Windows NT/95/9,* Washington, DC, 2001.

Henriksen, A.D. and Traynor, A.J., "A Practical R&D Project-Selection Scoring Tool", *IEEE Transactions on Engineering Management,* v.46, no. 2, 2 May 1999.

ILOG Corporation, *CPLEX Version 6.6.1,* Incline Village, NV, 2002.

Kim, G.C. and Emery, J., "An Application of Zero-One Goal Programming in Project Selection and Resource Planning-A Case Study from the Woodward Governor Company", *Computers and Operations Research,* v. 27, i. 14, 2000.

Klug, C. and Lynah, P., Assistant Chief of Staff for Installation Management, "Army Facilities Strategy Project Review Board Guidance",(U) http://www.hqda.army.mil/acsimweb/doc/ Encl2AFSProjects.doc, November 2001.

Lee, J.W and Kim, S.H., "Using Analytic Network Process and Goal Programming for Interdependent Information System Project Selection", *Computers and Operations Research,* v. 27, i. 4, 2000.

Microsoft Corporation, *Microsoft Excel 2000 ®,* Redmond, WA, 1999.

MILCON Process Seminar Guide Book FY 2001/2002.

Machacha, L. and Bhattacharya, P., "A Fuzzy-Logic-Based Approach to Project-Selection", *IEEE Transactions on Engineering Management,* v.47, no. 1, 2 February 2000.

Mukherjee, K. and Bera, A., "Application of Goal Programming in Project Selection Decision-A Case Study from the Indian Coal Mining Industry", *European Journal of Operational Research,* v. 82, i. 1, 1995.

Newman, A.M., Brown, G.G., Dell, R.F., Giddings, A., and Rosenthal, R.E., "An Integer-Linear Program to Plan Procurement and Deployment of Space and Missile Assets", Naval Postgraduate School Operations Research Technical Report 00-005, April 2000.

Navy Facilities Engineering Command, "Commanding Officer's Guide to Public Works", http//www.navfac.navy.mil, June 1999.

Nerger, J., Director of Facilities and Housing, Office of the Assistant Chief of Staff for Installation Management, Washington, DC, Interview with the author 14 December 2001.

R&K Engineering, Inc, "Real Property Planning and Analysis System",(U)http://rkeng.com, January 2002.

Rutherford, T. and Maliyev, A., *THE GAMS-Excel Interface,* Department of Economics-University of Colorado, (U)http://debreu.colorado.edu/xllink/xldoc.htm, March 2002.

Ryan, M., "Installation Status Report ISR infrastructure", Fiscal Year 2002 Implementing Instructions, 14 December 2001.

Smith, K., LTC, USAF, "Air Force Military Construction Prioritization Process", Briefing to Office of the Secretary of Defense, November 1999.

Sugiyama, D., A white paper, “MILCON Prioritization Process-Scoring Model”, Construction Division, Office of the Assistant Chief of Staff for Installation Management, December 2001.

Tamilin, P., Construction Division, Office of the Assistant Chief of Staff for Installation Management, Washington, DC, Interviews with the author 14 November-17 December 2001a.

Tamilin, P., Military Construction Process, “Briefing for General John N. Keane, Vice Chief of Staff,Army”, May 2001b.

Tarantino, W. J., “Prioritizing Army MILCON”, Draft Analysis Report from CAA, CAA-R-01-xx, Forthcoming.

Turner, A., “Navy MILCON Scoring Briefing”, Headquarters, Navy Facilities Engineering Command, December 2001.

United States Publishing Agency, DA PAM 415-15 “Army Military Construction Program Development and Execution”, 25 October 1999.

Van Antwerp, R., MG, USA, Assistant Chief of Staff for Installation Management, Washington, DC, Interview with author on 13 December 2001.

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Center for Army Analysis
   6001 Goethals Road, ATTN: LTC William J. Tarantino
   Fort Belvoir, VA

4. Department of the Army
   Office of the Assistant Chief of Staff for Installation Management
   Construction Division, ATTN: Pete Tamilin
   Washington, DC

5. Professor Robert F. Dell
   Naval Postgraduate School
   Monterey, CA

6. Professor Eva D. Regnier
   Naval Postgraduate School
   Monterey, CA